Short-term Chronic Toxicity of Photocatalytic Nanoparticles to Bacteria, Algae, and Zooplankton

C. P. Huang
University of Delaware

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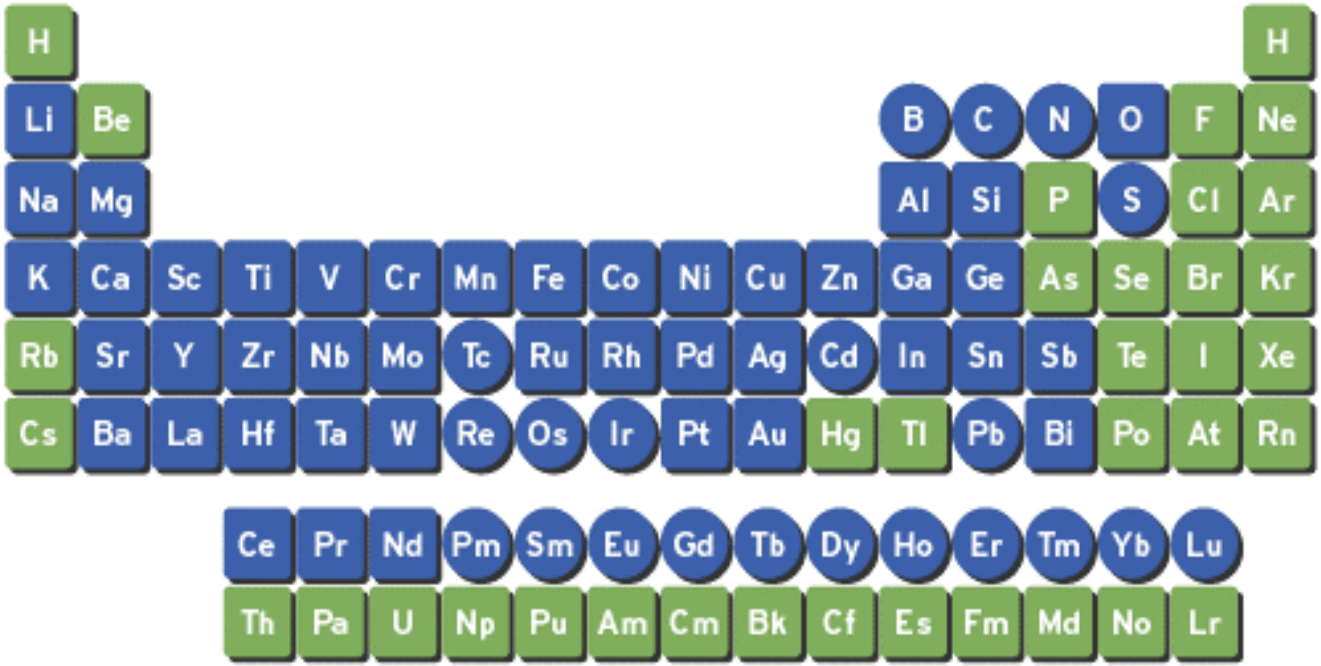
The Research Team

- **Prof. C. P. Huang**
- **Prof. Dan Cha**
- **Prof. Ismat Shah**
- **Dr. Y. C. Huang**
- **Ayca Erdem: Ph. D. student**
- **M. Y. Lin: Ph. D. student**
- **H. Y. Lin: Ph. D. student**
- **Rovshan Mahmudov: Ph. D. student**

NANOTECHNOLOGY

"The creation, processing,characterization and utilization of materials, devices, and systems with dimensions on the order of 0.1 to 100 nanometers, exhibiting novel and significantly enhanced physical, chemical, and biological properties, functions, phenomena, and processes due to their nanoscale size." **American Ceramic Society Bulletin (2003)**

The Periodic Table of Nanoparticles



Element already used to produce single and multi-metal nanoscale powders **43**

Element available in near future **22**

Element is radioactive, gaseous, or not preferred **36**

http://www.nanoproducts.com/site/content_page.php?p=powders.

Objectives

(1) To determine the acute toxicity of photocatalytic nanoparticles to a mixed bacterial culture,

(2) To determine the short-term chronic toxicity of photocatalytic nanoparticles to pure bacterial culture, daphnia and green algae,

(3) To determine the short-term chronic toxicity of copper(II) to green algae in the presence of photocatalytic nanoparticles, and

(4) To determine the short-term chronic toxicity of chlorinated phenols to pure bacteria culture, and dephnia in the presence of photocatalytic nanoparticles.

Particle Characteristics

- **Size**
  - procaryotic cells: 0.3 – 2 mm (or 300 – 2000 nm)
  - eucaryotic cells: 2 – 20 mm (or 2000 – 20000 nm)
  - nano-particles: 0.1 – 100 nm
- **Surface charge**
- **Chemical composition**
- **Photocatalysis**

Particle Size

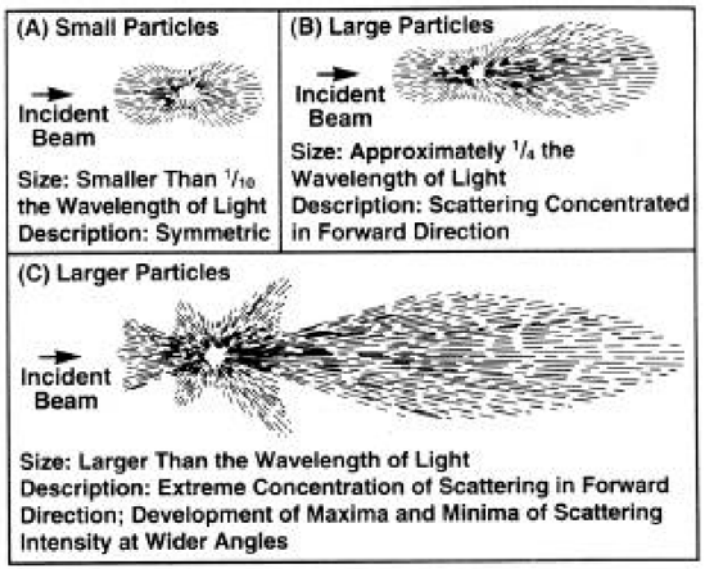
- **Turbidity**
- **Solubility**
- **Collision**

$$\tau \propto \frac{d^6}{\lambda^4}$$

$$K_{so} = K_{so}^{o} e^{-\frac{12\gamma}{3\rho RTd}}$$

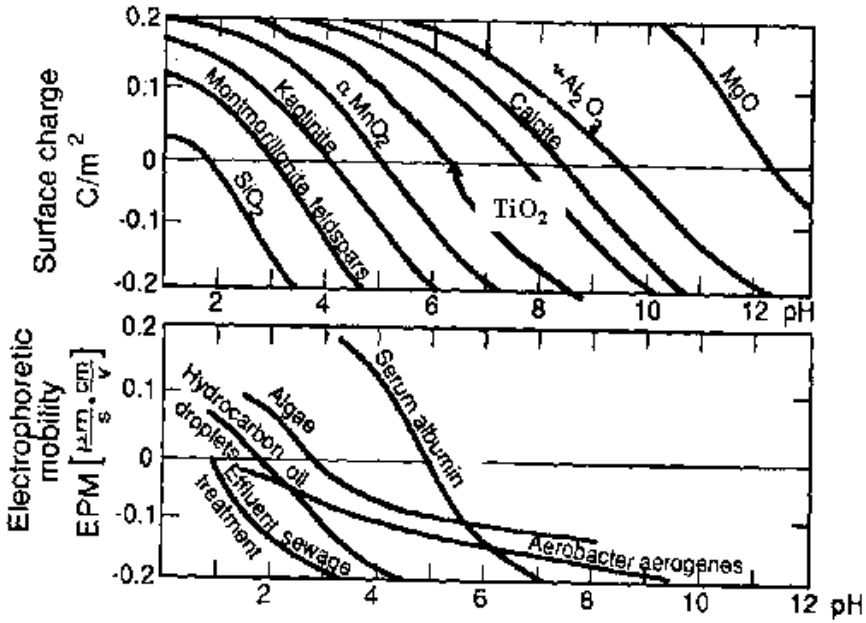
$$\beta_{kj} = 2\pi\left(d_j + d_k\right)\left(D_j + D_k\right)$$

$$D = \frac{\kappa T}{6\pi\eta r}$$

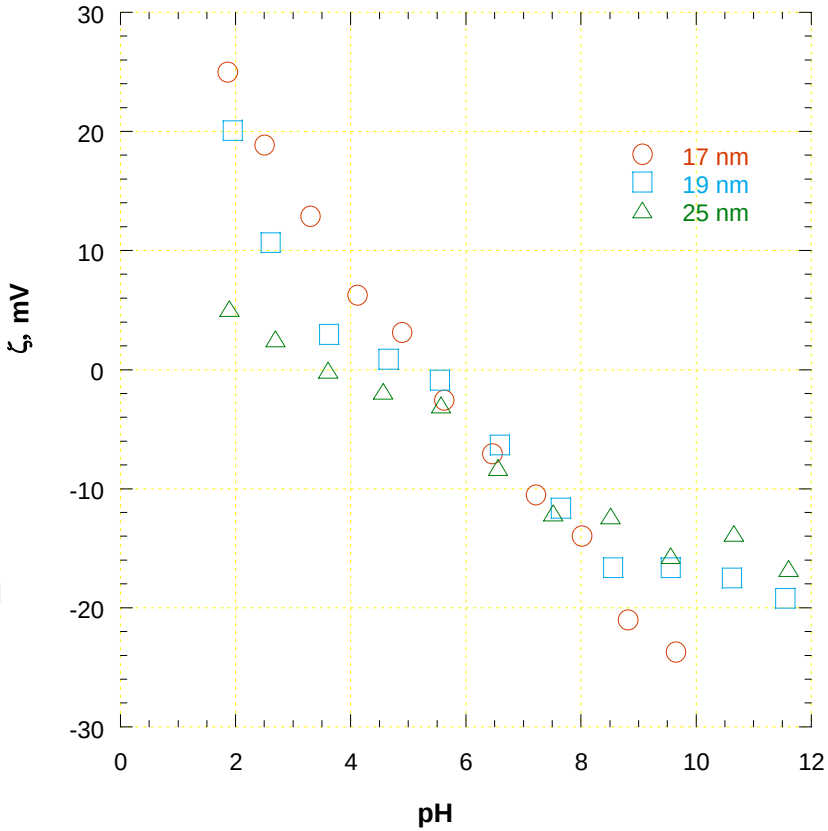


(Sadar 1996)

Surface Charge

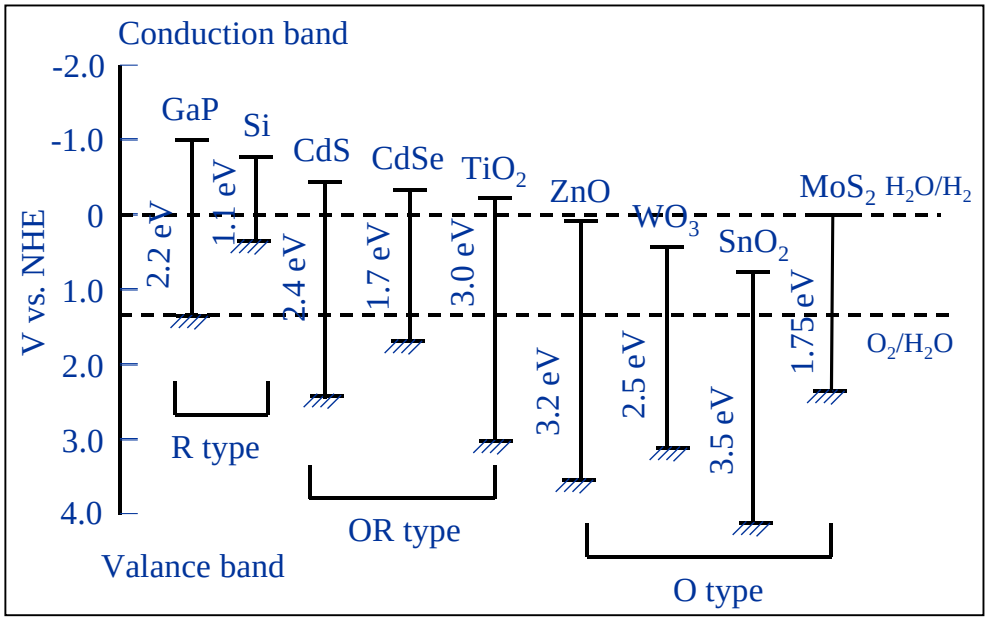


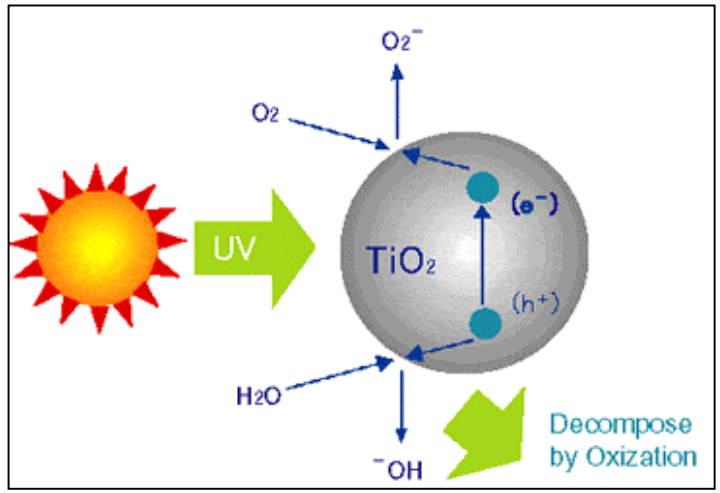
Surface charge of typical nanoparticles and biological substances (Stumm and Morgan, 1996)

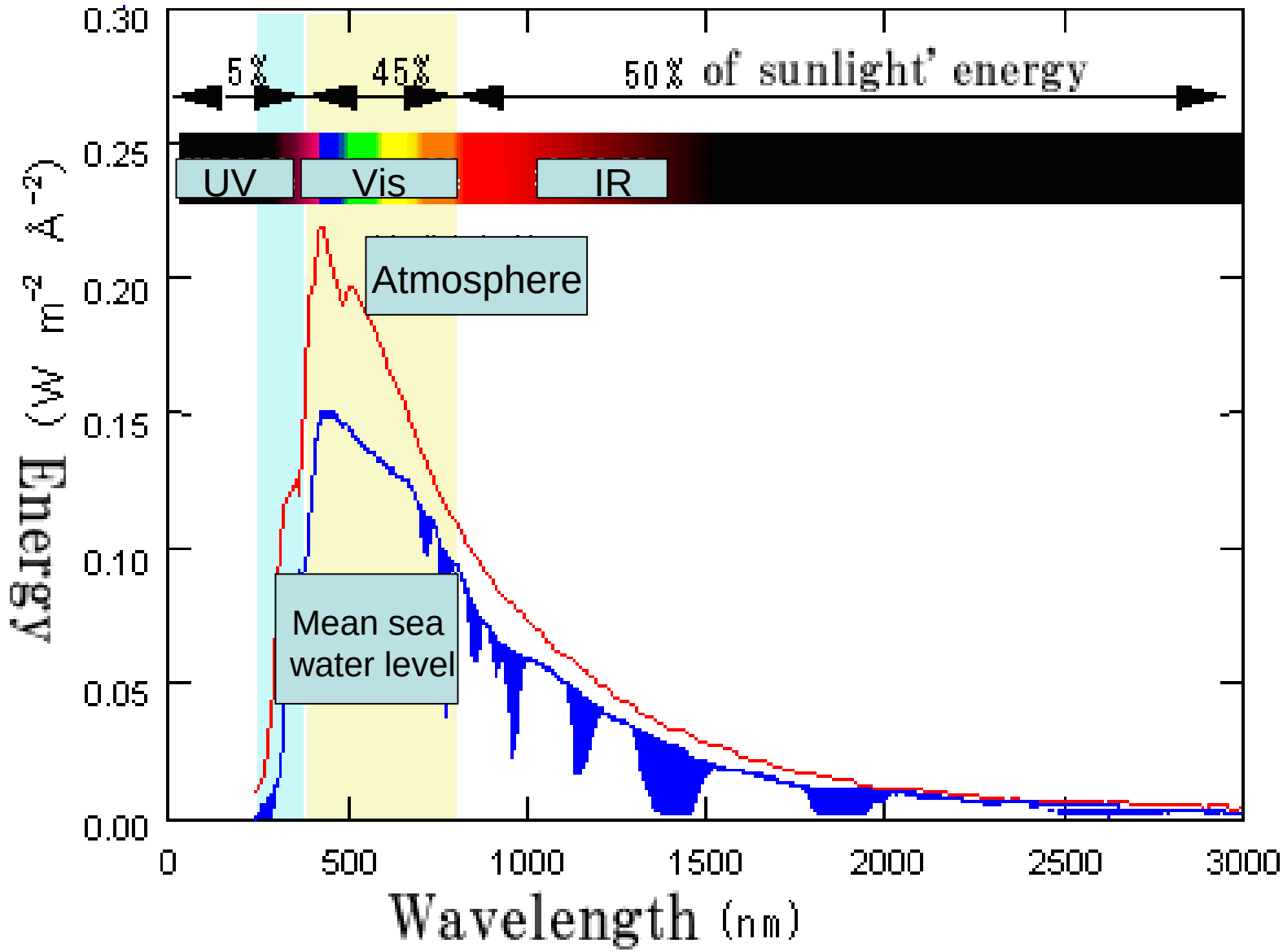


Effect of particle size on the surface charge of nano-TiO_2 particles

Photocatalyst





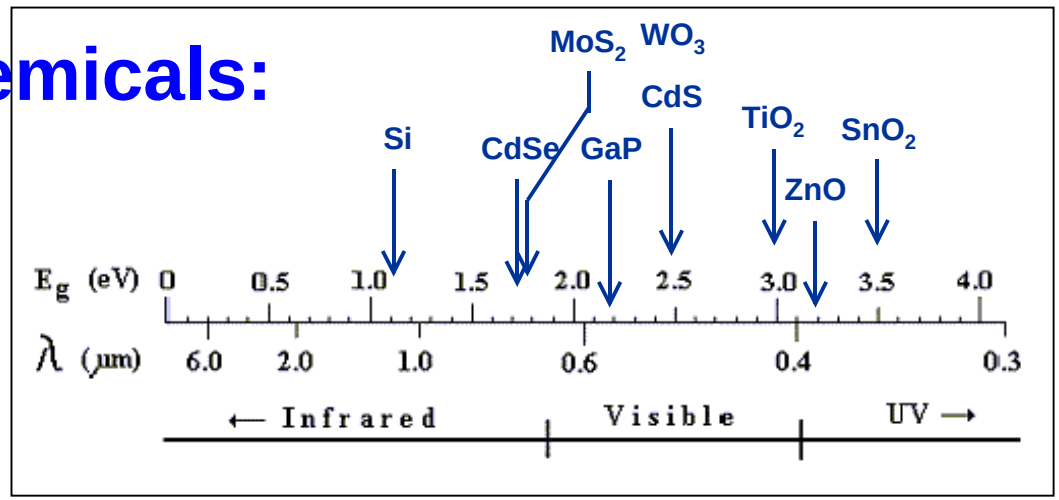

0.30
0.25
0.20
0.15
0.10
0.05
0.00
Energy (W m-2 λ-1)
5%
45%
50% of sunlight' energy
UV
Vis
IR
Atmosphere
Mean sea water level
0
500
1000
1500
2000
2500
3000
Wavelength (nm)

Test Organisms

- **Bacterial: E. coli; mixed cultures (Microcat-XR)**
- **Green algae: *Selenastrum capricornutum; algal assemblies***
- **Zooplankton: *Ceriodaphnia dubia***

Testing Conditions

- **Photocatalysts:**
  - **IR-sensitive: CdSe, MoS_2**
  - **Visible light-sensitive: GaP, CdS**
  - **UV-sensitive: TiO_2; ZnO; SnO_2**
- **Soluble toxic chemicals:**
  - **Cu(II)**
  - **Chlorinated HCs**



Toxicity Observation

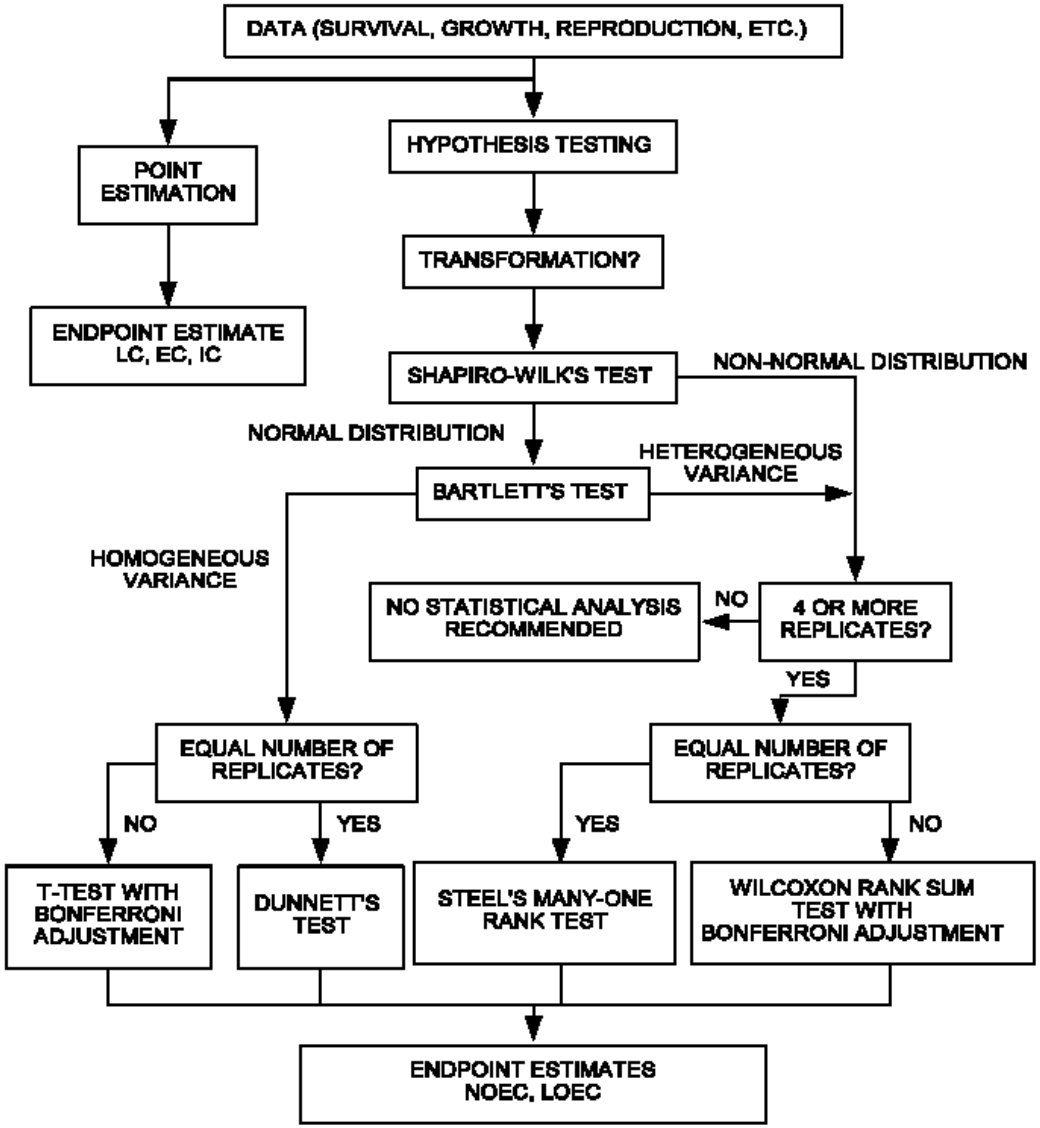
- Bacteria:
  - Metabolic activities : Respiration (oxygen demand, biokinetis constant)
  - Die-off
  - Lipid peroxidation: Malondialdehyde (MDA)
  - DNA sequencing
  - TEM, SEM
- Algae
  - Cell density
  - Chlorophyll
  - TEM, SEM
- Zooplankton
  - Survival
  - Reproduction
  - SEM, TEM

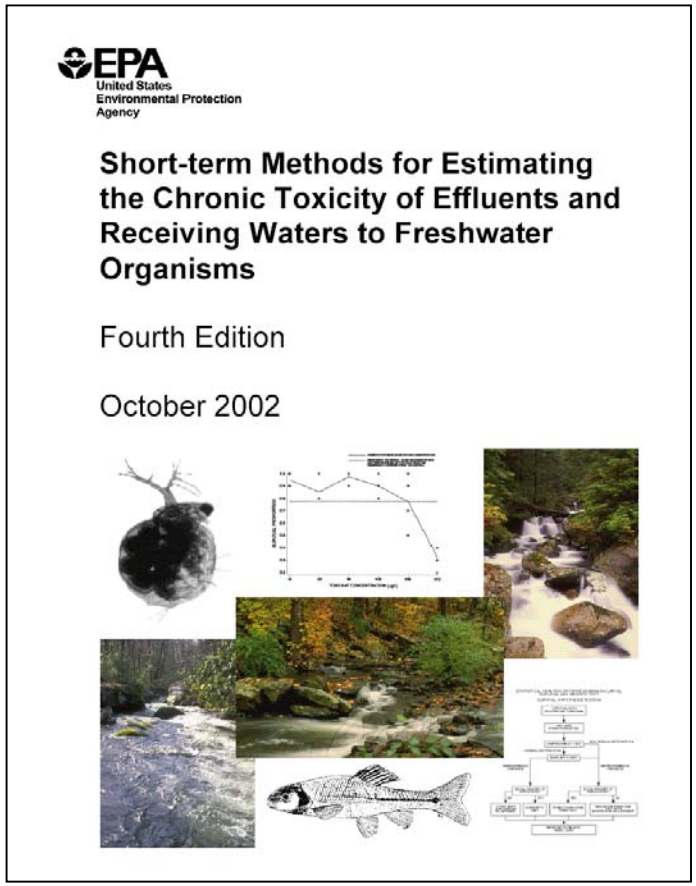
Point estimation techniques

LC50; IC25; IC50; EC50

Statistical analysis (Fisher, Dunnett, Steel)

LEOC ; NEOC


DATA (SURVIVAL, GROWTH, REPRODUCTION, ETC.)
POINT ESTIMATION
HYPOTHESIS TESTING
ENDPOINT ESTIMATE LC, EC, IC
TRANSFORMATION?
SHAPIRO-WILK'S TEST
NON-NORMAL DISTRIBUTION
NORMAL DISTRIBUTION
HETEROGENEOUS VARIANCE
BARTLETT'S TEST
HOMOGENEOUS VARIANCE
NO STATISTICAL ANALYSIS RECOMMENDED
NO
4 OR MORE REPLICATES?
YES
EQUAL NUMBER OF REPLICATES?
EQUAL NUMBER OF REPLICATES?
NO
YES
YES
NO
T-TEST WITH BONFERRONI ADJUSTMENT
DUNNETT'S TEST
STEEL'S MANY-ONE RANK TEST
WILCOXON RANK SUM TEST WITH BONFERRONI ADJUSTMENT
ENDPOINT ESTIMATES NOEC, LOEC


EPA
United States
Environmental Protection
Agency
Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms
Fourth Edition
October 2002

Expected Results

- **Determine the IC50, LC50, LEOC, NEOC values of selected testing organisms in the presence of selected photocatalytic nanoparticles.**
- **Understand the mechanism of the eco-toxicity of nano-particles: particle size, chemical composition, surface charges and photocatalysis.**
- **Understand the ecotoxicity of chemical hazards as affected by potocatalytic nanoparticles.**